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Agronomic Characteristics of Upland Red Rice Lines Resulted from Crossing IPB3S and Promising Line of Red Rice in Medium Elevation Areas

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Abstract— *Red rice is one of the important functional food sources because its anthocyanin content is very beneficial for human health. One of the processes to produce new superior varieties of rice is by cross-breeding. The aim of this study was to determine the agronomic performance of the promising lines of red rice resulted from crossing of IPB3S variety with the promising line of red rice compared with the parents and comparison genotypes in the medium elevation lands. The experiment was carried out in June - September 2022 in medium lowland rice fields (375 m asl) in Central Lombok district, NTB, Indonesia, which was designed using a Randomized Block Design (RCBD) consisting of 14 treatments, namely 9 ideal type red rice lines resulted from Pedigree F5 selection, 1 promising line of red rice from crosses between Kenya and Angka, two parents (the promising line of paddy red rice "GH F2BC4P19-36", and IPB3S variety), and two control varieties (Situ Patenggang and Inpago Unram 1), repeated 3 times. Observation variables included plant height, days to harvest, number of productive and non-productive tillers, length of panicles, number of filled and unfilled grains per panicle, weight of 100 grains, grain weight per clump and yield potential (tons/ha). The results showed that the red rice line G6 (F5 IPB3S/F2BC4P19-63// Fat/F2BC4P19-63-PD3/17) showed higher grain yield potential (4.79 t/ha) compared to the two parents, namely IPB3S (3.34 t /ha), GH parent (3.27 t/ha), Situ Patenggang (3.92 t/ha) and Inpago Unram 1 (3.35 t/ha). Plant height, number of productive and non-productive tillers per clump, panicle length, numbers of filled and unfilled grains per panicle, grain weight per clump and potential grain yield per hectare were significantly different between genotypes while days to harvest and 100-grain weight were not significantly different.*

Keywords— ***Red rice lines, upland rice, medium plains, cross-breeding, yield potential***

I. INTRODUCTION

The development of upland rice cultivars is an alternative to increasing national rice production, because the expansion of lowland rice is increasingly difficult to implement. One of the strategies that can be implemented is to utilize unused land and to use varieties that are adaptive to the upland environment. In Indonesia, there are around 2 million ha of dry or rainfed land suitable for upland rice. However, the average national productivity of upland rice in Indonesia is still around 2.36 tons/ha, far below the average productivity of paddy rice, which is on average 4.98 tons/ha (BPS, 2021) [1]. Therefore it is necessary to carry out research activities to develop genotypes that are tolerant to drought stress to increase the productivity of upland rice [2]. Improving the agronomic characteristics of upland rice can be carried out using various plant breeding methods, one of which is by carrying out crosses between germplasms that have the opportunity to produce new superior upland rice varieties.

Red rice is one of the local germplasm whose grains contain anthocyanins, which are very beneficial for human health. Red rice is efficacious for increasing the body's resistance to disease, repairing damage to liver cells (hepatitis and cirrhosis), preventing impaired kidney function, preventing cancer/tumors, slowing aging, functioning as an antioxidant, cleaning cholesterol in the

blood, and preventing anemia. The existence of red rice in Indonesia is increasingly scarce due to the planting of new superior rice varieties which are dominated by white rice [3-6].

The superior varieties released by the Ministry of Agriculture to date amount to more than 233 varieties consisting of 144 superior varieties of inbred lowland rice (INPARI), 35 hybrid rice varieties (HIPA), 30 superior varieties of upland rice (INPAGO) and 24 swamp rice varieties (INPARA), and most of these varieties were produced by the Agency for Agricultural Research and Development [7]. Several varieties have been released by several universities such as IPB with its varieties IPB 3S and IPB 4S (2012) in the form of lowland rice varieties, UNSOED with INPAGO Unsoed 1 (2011) and UNRAM with INPAGO UNRAM 1 (2011) through the activities of the National Rice Consortium, which was initiated by the Sukamandi Rice Research Center. Almost all of the high yielding rice varieties released were white rice, except for INPAGO Unram I, which is a superior variety of upland red rice. Meanwhile, the ideal type of superior varieties of upland red rice has not yet been released.

Sources of new genes that have the potential to lead to the formation of superior varieties of upland rice of the ideal type which have the potential for high yields and early maturaty are urgently needed considering that there is still a lot of germplasms for these traits that have not been identified. From the results of research conducted by Aryana et al. [8] through back crosses of four times between the promising line of drought tolerant red rice and the local cultivar of red rice “Kala Isi Tolo” (which has high anthocyanin content and early maturity) has produced the promising line of upland red rice “GH F2BC4P19-36” (which has high anthocyanin content, large number of tillers, and early maturity (107 days), but still has a relatively low yield of 5.8 tons/ha). This promising line was then crossed with IPB 3S (which has a yield potential of 11.2 tons/ha, 112 days maturity, the texture of rice is fluffier with white rice color, the number of tillers is low) through single crosses and repeated cross selection, which was then followed by Pedigree selection until F5, resulting in new superior red rice lines of ideal types [9]. These lines have not been tested for their agronomic properties in medium upland plains. Therefore, the purpose of this study was to determine the agronomic performance of the red rice lines on medium elevation dry land.

II. MATERIALS AND METHODS

The experiment was carried out in medium plain rice fields in the village of Tampak Siring Mujur, North Batukliang sub-district, Central Lombok, West Nusa Tenggara, with an elevation of 375 m above sea level, from June to September 2022. The experiment was arranged using a Randomized Block Design consisting of 14 treatments (Table 1), namely 9 upland red rice lines of ideal types resulted from F5 Pedigree selection (G1 to G9), 1 promising line of red rice from crosses of “Kenya” with “Angka” variety (G10), 2 parents (the promising line of red rice “GH F2BC4P19-36” (G11) and IPB3S (G12)), and comparison upland varieties (Situ Patenggang and Inpago Unram 1), which were repeated 3 times.

Table 1. Rice genotypes tested in this experiment

Treat-ments	Genotypes
G1	F5 IPB3S/F2BC4P19-63// Fat/F2BC4P19-63-PD3/7
G2	F5IPB3S/F2BC4P19-63// Fat/F2BC4P19-63-PD3/15
G3	F5 IPB3S/F2BC4P19-63// Fat/F2BC4P19-63-PD3/20
G4	F5 IPB3S/F2BC4P19-63// Fat/F2BC4P19-63-PD3/13
G5	F5 IPB3S/F2BC4P19-63// Fat/F2BC4P19-63-PD3/71
G6	F5 IPB3S/F2BC4P19-63// Fat/F2BC4P19-63-PD3/17
G7	F5IPB3S/F2BC4P19-63// Fat/F2BC4P19-63-PD3/25
G8	F5 IPB3S/F2BC4P19-63// Fat/F2BC4P19-63-PD3/30
G9	F5 IPB3S/F2BC4P19-63// Fat/F2BC4P19-63-PD3/23
G10	The promising line “GH-SBCSKA”
G11	“IPB 3S” parent variety
G12	GH parent line of red rice (GH TM)
G13	“Situ Patenggang” upland white rice variety (SP)
G14	“Inpago Unram 1” upland red rice variety (IU-1)

The observed variables included plant height, days to harvest, number of productive and non-productive tillers, panicle length, number of filled and unfilled grains per panicle, weight of 100 filled grains, grain yield per clump and potential yield of tons/ha with a moisture content of 14% (which was converted from the grain yield of 1 m^2 to tons/ha). Each treatment genotype was planted in as upland rice in 2 x 4 m plots, plant spacing of 25 x 25 cm, with 1 plant per hill, fertilized with Phonska 15-15-15 fertilizer as basal fertilization (300 kg/ha), and Urea (45% N) dibbled at 50 days after seeding (200 kg/ha). The data were analyzed with analysis of variance (ANOVA) and DMRT (Duncan Multiple Range Test) at 5% significance level, which was carried out using the SAS program.

III. RESULTS AND DISCUSSION

Based on the results of the analysis of variance (ANOVA), all variables showed significant differences between the

genotypes tested, except for the days to harvest and the weight of 100 filled grains (Table 2).

Table 2. Summary of the ANOVA results `

Variables	**p-value**	**Sig**
Days to harvest (DTH)	0.2363	ns
Plant height (PH)	0.0001	s
Number of productive tillers (NPT)	0.0362	s
Number of non-productive tillers (NNPT)	0.0028	s
Panicle length (PL)	0.0001	s
Number of filled grains per panicle (NFGP)	0.0001	s
Number of unfilled grains per panicle (NUGP)	0.0001	s
Weight of 100 filled grains (W100)	0.2312	ns
Grain yield per clump (GYC)	0.0005	s
Potential yield per ha (PYH)	0.0001	s

When the rice plants have reached optimum maturity, they are ready to be harvested. Harvesting can usually be done 30 days after flowering [10]. The Rice Research Center classifies the maturity of rice plants as ultra early maturity <90 days, very early maturity 90-104 days, early maturity 105-124 h; moderate maturity 124-150 days; and late maturity >150 days. Based on this classification, all the genotypes tested were categorized as early maturity, which ranged from 110 days to 112 days to harvest (Table 3). However, the days to harvest for all the genotypes tested was not significantly different between genotypes (Table 2).

Plant height is a measure that is often observed as an indicator of growth as well as a variable used to determine crop production [11]. IRRI [12] classifies plant height into short (<110 cm), medium (110-130 cm) and tall (>130 cm) categories. Based on these categories, all the rice lines tested were classified as having medium plant height, except for G2 (133.64) and G8 (130.67 cm), which were classified as tall genotype. Rice plants that are classified as tall tend to fall down easily as a result of environmental factors such as strong winds, which usually decrease grain yields. Zen [13] added that dwarf plants will avoid being collapse due to the wind, so these plants are easy to care for.

The number of productive tillers per clump ranged from 8.30 to 13.54 (Table 3). The lowest number of productive tillers was found in the variety “Situ Patenggang” (8.30), and the highest number was in the G4 line (13.54). There was no difference in the number of productive tillers between lines and with the two parents (Table 2). According to Endrizal et al. [14], productive tillers per clump is the number of panicles, thus these tillers have a direct effect on the high and low grain yields. Hatta [15] added that the number of productive tillers is related to yield, and a small number of productive tillers can reduce yields. Aryana et al. [8] also added that the tillers formed in the final stages of the vegetative phase tended to be unable to produce panicles, while the number of non-productive tillers between lines resulting from crosses of IPB3S vs. GH TM as well as vs both parents and the comparison varieties were not significantly different (Tabel 3). Thamrin et al. [16] stated that non-productive tillers are competitors to productive tillers in utilizing solar energy and nutrients. In addition, the more non-productive tillers, the more humid the micro-environment will be, thus providing opportunities for the development of pests and diseases.

Panicle length is a selection criterion for rice plants because it affects yield. Of all the genotypes tested, the panicle length ranged from 19.74 – 25.57 cm (Table 3). The panicle length is classified into 3 (three) categories, namely short panicles (<20 cm), medium panicles (20-30 cm) and long panicles (> 30 cm) [17]. Based on this classification, all genotypes showed medium panicle length (20-30 cm). Plants that have long panicles will produce more grains so that the yields are higher [18]. The highest panicle length was seen in the lines G2 (25.53 cm) and G6 (25.57 cm) and was different from the two parents.

The number of filled grain per panicle ranged from 86.20 (in IPB3S variety) – 163.43 (in the Situ Patenggang variety). All the lines showed higher filled grain number than the IPB3S parents except for the G5 (98.68 grains) and G9 (103.42 grains) (Table 4). Bobihoe and Nafisah [19] stated that the number of filled grains per panicle correlated with rice yields but was also influenced by the number of unfilled grains. Rice yield is determined by several yield components such as the number of filled grains per panicle, the number of panicles per clump and the weight of 100 grains. Wibowo [20] added that each genotype has a different ability to produce filled grains depending on its genetic characteristics.

Table 3. Average days to maturity, plant height, panicle length, productive and non-productive tiller number per clump for each genotype tested

Treatment	Days to harvest	Plant height (cm)	Panicle length (cm)	Productive tillers per clump	Non-productive tillers per clump
G1	110.34 a	114.60 c	24.28 ab	11.04 ab	2.74 bc
G2	111.67 a	133.64 a	25.53 a	10.54 bc	1.87 c
G3	112.34 a	126.20 b	24.35 ab	12.20 ab	1.97 c
G4	110.67 a	129.27 ab	23.02 bc	13.54 a	2.40 c
G5	111.67 a	110.47 cd	20.55 ef	11.67 ab	3.47 bc
G6	110.67 a	125.20 b	25.57 a	11.40 ab	2.70 bc
G7	111.34 a	115.05 c	21.52 cdef	9.64 bc	3.30 bc
G8	111.34 a	130.67 ab	22.14 cde	12.30 ab	1.80 c
G9	112.00 a	111.17 cd	21.01 def	7.83 bc	4.40 ab
G10/GH-AK	111.00 a	109.94 cd	19.74 f	11.34 ab	5.27 a
G11/IPB3S	111.34 a	111.44 cd	20.71 def	11.00 ab	3.04 bc
G12/GH-TM	112.00 a	116.50 c	22.28 cde	11.34 ab	2.20 c
G13/SP	111.00 a	107.00 d	22.60 bcd	8.30 c	1.80 c
G14/IU-1	110.34 a	125.70 b	21.20 cdef	11.44 ab	3.17 bc

Table 4. Average filled and unfilled grain number per clump, weight of 100 grains, grain yield per clump, and potential yield per ha for each genotype tested

Treatment	Filled grain number per panicle	Unfilled grain number per panicle	Weight of 100 grains	Grain yield (g/clump)	Potential yield (ton/ha)
G1	115.17 cd	40.60 ab	3.06	28.11 bcd	3.52 de
G2	143.21 ab	48.73 a	3.02	35.86 ab	3.50 de
G3	113.93 cd	36.47 abc	3.17	38.16 a	3.57 e
G4	128.92 bc	23.84 cd	2.99	33.93 abc	3.26 cde
G5	98.69 de	25.49 cd	3.13	22.47 d	3.34 abc
G6	151.46 ab	48.69 a	3.22	38.82 a	4.79 a
G7	122.52 bcd	31.36 bcd	3.24	33.24 abc	4.57 ab
G8	132.02 bc	24.17 cd	2.96	38.05 a	4.15 abcd
G9	103.42 de	25.05 cd	3.09	22.73 d	4.24 abc
G10/GH-AK	89.63 e	22.44 cd	3.16	25.13 cd	3.54 de
G11/IPB3S	86.20 e	24.12 cd	3.21	22.10 d	3.34 e
G12/GH-TM	139.82 ab	44.85 a	3.11	32.98 abc	3.27 e
G13/SP	163.43 a	31.08 bcd	2.93	36.71 ab	3.92 bcde
G14/IU-1	102.81 de	21.04 d	3.15	30.36 abcd	3.35 e

The high number of unfilled grains was found in the lines G2, G6 and the parent G12/GH-TM, namely 48.73; 48.69 and 44.85 grains per panicle and the lowest was in the comparison variety Inpago Unram 1 (21.04 grains per panicle). The level of unfilled grain number, apart from being a genetic influence, can also be influenced by

environmental factors [10]. Peng et al. [21] stated that the low seed filling rate was the result of a small apical dominance in the panicle, grain arrangement in the panicle, and limited vascular sheaths for assimilate transport to the panicles.

The weight of 100 filled grains was not significantly different between treatments (Table 4). However, the highest weight was seen in the line G7 (3.24 g) and the lowest in the “Situ Patenggang” upland rice variety (2.93 g). According to Ma et al. [22], for ideal type of rice, the weight of 1000 grains is between 28-30 g. The weight of 1000 grains is a component that affects the grain yield. The heavier the 1000 grains, the higher the grain yield will be [23].

Grain yield per clump of rice plants is generally strongly influenced by the number of filled grains, panicle length, number of panicles per clump, and 1000 grain weight [24]. Aryana et al. [10] also indicated that the amount of filled grains determines the weight of grain per clump. This can be seen in the G6 genotype which has long panicles, a relatively large number of filled grains per panicle and a high weight of 100 grains, resulted in a higher grain yield per clump in the G6 genotype, when compared with the two parents IPB3S (G11) and GH-TM (G12), which have shorter panicle lengths, small amount of filled grains per panicle and the lower 100 grain weight (Table 4).

The potential grain yield per hectare is a quantity that describes the amount of yield obtained in one ha of land in one planting cycle. According to Aryana et al. [10], high yields in rice plants can be caused by high yield components, such as panicle length, number of filled grains per panicle, and grain weight per clump. The G6 genotype, which is a red rice line resulted from a cross between the parents IPB3S and the promising line of red rice (GH-TM), had higher yield potential compared to both parents and the comparison varieties (Situ Patenggang and Inpago Unram 1) under upland growing conditions in medium elevation areas.

IV. CONCLUSION

From the results, it can be concluded that the G6 rice line (F5 IPB3S/F2BC4P19-63// Fat/F2BC4P19-63-PD3/17) showed higher yield potential (4.79 t/ha) compared with its two parents, namely IPB3S (3.34 t/ha), GH red parent (3.27 t/ha), and the comparison varieties “Situ Patenggang” (3.92 t/ha), and “Inpago Unram 1” (3.35 t/ha). Plant height, number of productive and non-productive tillers per clump, panicle length, number of filled and unfilled grains per panicle, grain yield per clump and potential grain yield per hectare showed significant differences between genotypes while days to harvest and weight of 100 grains were not significantly different between genotypes.

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